REMARKS

Applicants' undersigned Attorney would like to thank Examiner Rhee and her supervisor, Examiner Pyon, for the courtesies extended during the interview of April 8, 2003. During the interview, the rejections of the claims under 35 U.S.C. §112, second paragraph and under 35 U.S.C. §102 as being anticipated by Barre were discussed. The merits of these discussions are addressed below in the context of the Examiner's rejections and Applicant's responses thereto.

In the Office Action mailed December 11, 2002, the claims were rejected under 35 U.S.C. §112, second paragraph, since the Examiner alleges that the term "CLO" renders the claim indefinite. The Examiner states that the term "CLO" is not defined by the claim, the specification does not provide a standard for defining the requisite degree, and one of ordinary skill in the art would not be reasonably apprised of the scope of the invention. Applicant respectfully traverses this rejection. On page 4 of the specification, lines 25 – 30, Applicant defines CLO as a unit of thermal resistance of a garment. This term is known in the art, as it is defined in Textile Terms and Definitions", Tenth Edition, the Textile Institute, (1995), pp. 66, 350, as noted on page 4 of the specification. *Moreover, Applicant explains exactly how they measure CLO for their Examples on pages 15 and 16 of the specification.* Thus, Applicant believes that the Examiner's characterization of the term "CLO" as indefinite is unfounded and the rejection of the claims under 35 U.S.C. §112, second paragraph should be withdrawn. These points were discussed during the Interview, and the Examiners agreed that Applicant has in fact described how to measure CLO in the specification, and thus, the use of the term "CLO" in the claims does not render the claims indefinite. It was agreed that the rejection of the claims under 35 U.S.C. §112, second paragraph, should be withdrawn.

Claims 1 – 6, 8, 9, 11, 18 and 19 were rejected under 35 U.S.C. §102(e) as being anticipated by Barre. Claims 7 and 10 were rejected under 35 U.S.C. §103(a) as being unpatentable over Barre in view of Pusateri et al. This rejection is respectfully traversed. The Examiner states that on page 2 of the Office Action that Barre discloses an insulating label stock comprising an insulating layer, referring to column 2, lines 28 – 30. Barre discloses in this passage that the nonwoven material may be a nonwoven of thermoplastic fibers, especially polyolefin fibers, such as polypropylene or polyethylene fibers, or polyester fibers. Barre further discloses on column 3, lines 31 – 24 that a polyolefin material, especially a polypropylene or

polyethylene nonwoven material, is used for nonwoven film 8. As a variant, a polyester non-woven material is used. The greatest range for the thickness of film 8 is given on column 2, lines 37 – 39, which disclose that the film of nonwoven material has a thickness of from 20 µm to 500 µm , and preferably from 100 µm to 300 µm. It is respectfully submitted that none of these materials at these thicknesses has a thermal resistance value in Applicant's claimed range of 0.05 to 0.5 CLO (0.0077 to 0.077 $m^2 \cdot K/W$). In order to show this, Applicant has included Attachment A, in which Applicant calculates the thermal resistance values for these materials, including polyethylene terephthalate, which is also polyester, at a minimum thickness of 20 µm and a maximum thickness of 500 µm. The references which Applicant used to make these calculations are attached hereto as Attachments B – D, and these Attachments are listed on the Second Supplemental Information Disclosure Statement, filed concurrently herewith. As can be seen from the Table below, which is a compilation of the calculations done in Attachment A for the materials listed as the nonwoven film of Barre, all of the thermal resistance values for the materials of the nonwoven film of Barre at 20 µm and at 500 µm thicknesses fall outside of Applicant's claimed range for thermal resistance of 0.05 to 0.5 CLO (0.0077 to 0.077 $m^2 \cdot K/W$).

TABLE OF THERMAL RESISTANCE VALUES FOR NONWOVEN FILM OF BARRE

POLYMER	THERMAL RESISTANCE ($m^2 \cdot K/W$)	
	20 µm thickness	500 µm thickness
Polypropylene	0.00016	0.00417
40% talc-filled polypropylene	0.00006	0.00156
40% $CaCO_3$-filled polypropylene	0.00007	0.00172
40% glass-reinforced polypropylene	0.00005	0.00135
Low density polyethylene	0.00006	0.00151
Medium density polyethylene	0.00005	0.00119
High density polyethylene	0.00004	0.00096
Cast rigid polyester	0.00012	0.00294
Chlorinated polyester	0.00006	0.00151
Polyethylene terephthalate	0.00013	0.00333
30% glass reinforced polyethylene terephthalate	0.00007	0.00172

The Examiner interprets Barre with respect to claim 11 differently than with respect to claim 1. With respect to claim 11, the Examiner considers that reference number 2 in Fig. 1, the substrate, is analogous to Applicant's thermal insulating layer as recited in claim 11. However, substrate 2 in Barre is not a thermal insulating layer

having a thermal resistance in the range of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2.K/W) as recited in claim 11 as amended. On column 2, at lines 64 – 67, Barre discloses that printable substrate 2 is made of high-density polypropylene, of polypropylene, of polyvinyl chloride, of paper or of polyethylene terephthalate. On column 2, Barre discloses the greatest range for the thickness of the substrate to be about 20 μm to about 200 μm. On column 3, Barre discloses a thickness of about 80 to 100 μm for high-density polyethylene, 40 to 60 μm for polypropylene, and 100 μm for paper. The thermal resistance for these materials at 20 μm and 200 μm are calculated in Attachment A. As can be seen from the Table below, which is a compilation of the calculations done in Attachment A for the materials listed for the substrate in Barre, all of the thermal resistance values for the materials of the substrate of Barre at 20 μm and at 200 μm thicknesses fall outside of Applicant's claimed range for thermal resistance of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2·K/W).

TABLE OF THERMAL RESISTANCE VALUES FOR SUBSTRATE OF BARRE

POLYMER	THERMAL RESISTANCE (m^2·K/W)	
	20 μm thickness	200 μm thickness
Polyethylene terephthalate	0.00013	0.00133
30% glass reinforced Polyethylene terephthalate	0.00007	0.00069
High density polyethylene	0.00004	0.00038
40% talc-filled polypropylene	0.00006	0.00062
40% $CaCO_3$-filled polypropylene	0.00007	0.00069
40% glass-reinforced polypropylene	0.00005	0.00054
Rigid Polyvinylchloride	0.00010	0.00095
Flexible Polyvinylchloride	0.00012	0.00117
Chlorinated Polyvinylchloride	0.00014	0.00142
Paper[1]	0.00033	0.00333

Moreover, it is respectfully submitted that Pusateri fails to cure the deficiencies of Barre. It appears that the Examiner is calling layer 28 in Pusateri a thermal insulating

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[1] Numerous values are given for the thermal conductivity of paper in Attachment D. The calculation for thermal resistance of paper given in the Table above is based on a thermal conductivity of 6 x 10^{-2} W/(m*K). All of the thermal conductivities listed in Attachment D translate to thermal resistances which are less than Applicants' claimed ranged except for fine paper (thermal resistance of 0.01538 at a thickness of 200 um), which has a thermal conductivity of 1.3 x 10^{-2} at 30°C, 40% RH. However, there is no disclosure in Barre that the materials of the thermal insulating layer are used or their properties are measured under conditions other than room temperature.

layer which comprises foam. However, there is no disclosure of what material the foam is made of, and therefore it is impossible to allege that this foam has a thermal resistance value which falls within the scope of Applicant's claims.

Thus, it is respectfully submitted that independent claims 1 and 11 define over the prior art of record. Allowance of claim 1, and claims 2 – 4 and 6 – 10 and 20 – 24 which depend thereon, as well as allowance of claim 11, and claims 19, 25 and 26 which depend thereon, is respectfully requested for this reason.

During the interview, the Barre patent was discussed, and Applicant showed the Examiner a sample of the label stock made according to the present invention. The structure and the sealing of the label stock of the present invention were particularly highlighted in order to define Applicant's invention over the label stock described in the Barre patent, and Examiners Pyon and Rhee suggested that Applicant claim a label stock which has face material on both sides of the insulating layer, and which is sealed around its edges. Accordingly, by this Amendment, claim 31 has been added. This claim recites that that the label stock has an upper edge and a lower edge, and the upper and lower edges of the label stock are sealed. Antecedent basis for this amendment can be found in the specification on page 10, lines 19 – 22, which disclose that "The label stock of the present invention may be sealed, such as with a hot knife, at its edges so that fluid cannot penetrate the edges of the label stock. Such edges are shown at 132 in Figs. 3 – 6." Applicant notes that in Figs. 3 – 6, all of the edges 132 are at the top or the bottom of the label stock. In order to clarify which edges Applicant is referring to in the claims, Applicant proposes to amend the specification in order to state that, after the recited passage on line 22 of page 10, that, as can be seen from Figs. 3 – 6, these edges 132 include a top edge and a bottom edge, and thus amend claim 1 to recite such top and bottom edges. Applicant respectfully believes that the addition of such an explanation to the specification and of this language to claim 1 is not new matter, since these edges are clearly shown as top and bottom edges in Figs. 3 – 6. In addition, in a separate letter filed herewith, Applicants request the Examiner's approval of the suggested change to Figs. 3 – 6 to clearly call out the top edge 132a and the bottom edge 132b. Thus, entry of this amendment to the specification and to claim 1 is respectfully requested.

It is respectfully submitted that none of the prior art of record teaches a label stock that is sealed along its top and bottom edges as now claimed in claim 31. The Examiner states in the Office Action of December 11, 2002 on page 3 that Barre discloses that the label stock is sealed at its edges (figure 1 number 9 and 5). In Fig.

1 of Barre, 9 represents an adhesive composition which is put on the printable substrate 2. Reference number 5 is a side of a peel-off sheet 4 which is in contact with the adhesive composition 9. If the Examiner is implying that the peel-off sheet is "sealed" to the substrate 2 by adhesive composition 9, it is respectfully submitted that no seal is formed between 9 and 5 in Fig. 1 of Barre. There is absolutely no disclosure in Barre that the either 9 or 5 are sealed. They are simply surfaces which contact each other in Fig. 1. Moreover, Applicant is now claiming that the top edge and the bottom edge are sealed. Adhesive 9 and side 5 do not represent the top edge and the bottom edge of Barre.

Nor would there be any reason to seal the top edge or the bottom edge of Barre. Barre is concerned with improving the sensory aspects of a package, particularly its feel. Thus, Barre recognizes a demand for replacing the traditional feel of thermoplastic bottles with warmer, softer types of feel. (See column 1, lines 22 – 28). Applicants believe that the use of the term "warmer" is directed to the way the label feels, not the ability of the label to hold heat. There is no need in Barre to thermally insulate the contents of the package on which the label of Barre is used, since Barre is directed to a package for a cosmetic product, and particularly a label for bottle, such as those used for packaging shampoos, lotions, beauty creams or gels. Barre quite simply does not need to seal the edges of its label stock. Thus, one could not conceivably argue that the label of Barre is inherently sealed along its top and bottom edges or along its side edges.

It is noted that claim 5 as originally filed recites that the label stock is sealed at its edges. This claim has been canceled by this amendment so that its subject matter can be incorporated into claim 1. In the first Office Action, mailed June 5, 2002, the Examiner rejected claims 1 and 5 as being unpatentable over Frankosky in view of Hobson. The Examiner stated on page 5 of the Office Action that Frankosky discloses that the label stock is sealed at is edges, referring to column 2, lines 27 and 28. However, this disclosure says that the upper and lower faces of the batt are sealed. These surfaces would be analogous to the face material of the present invention. There is no disclosure in Frankosky that the upper and lower *edges* of the batt are sealed. Nor would there be any reason to seal the upper and lower edges of the batt of Frankosky, as this batt is used as insulating material for pillows, cushions or bedding material, or for apparel. It is used with shell fabrics, and the reason for sealing the batt on the top and bottom *surfaces* is to prevent fiber leakage through shell fabrics.

The Examiner cites Pusateri in order to teach that the face material is modified on the surface facing away from the thermal insulating layer to facilitate printing thereon and that the thermal insulating layer comprises foam. Pusateri does not teach a label stock having sealed top and bottom edges as now claimed. Nor is there any reason to believe that this teaching is inherent in Pusateri. Pusateri is directed to a method and apparatus for placing repositionable sheets directly onto advertising signatures. There is no reason to have sealed edges in this configuration, as this configuration is not being used as a thermal insulator as in the present invention. Thus, Pusateri fails to cure the deficiencies of Barre and Frankosky as discussed above.

Thus, it is respectfully submitted that none of the prior art of record discloses or even suggests an insulating label stock having upper and lower edges which are sealed. Allowance of claim 31, and claims 2 – 4, 6 – 10, 20, 23, 32 and 33 which depend thereon, is respectfully requested for this reason.

New claim 27 recites an insulating label, as opposed to an insulated label stock, with an upper edge, a lower edge, and a side edge disposed at each side between the upper and the lower edge, where the upper, lower and side edges of the label are sealed. Antecedent basis for this claim may be found in the specification on page 13, lines 30 – 34, which recites that "The formation of the label stock may be followed by cutting to desired widths with a hot knife which seals the edges of the label stock. The label stock may then be cut to form labels, which may preferable have sealed edges." In addition, antecedent basis for the concept of a sealed label can be found on page 10, lines 26 – 28, which disclose that a label made from the label stock of the present invention is preferably sealed so that fluid cannot penetrate the edges thereof. Applicants propose to amend the disclosure on page 13 to make it clear that the first seal referred to, the one made with the hot knife which seals the edges of the label stock, are the top and bottom edges 132a and 132b as discussed with respect to the label stock on page 10. When an insulating label is formed from the label stock of the present invention, the side edges of the label are also sealed, so that the label is completely sealed all the way around. The side edges are shown at 130 in Figs. 3 – 6. Applicants respectfully submit as this explanation is not new matter, as it is clear from the original disclosure on page 13 that Applicant is referring to sealing an additional set of edges when a cut is made to make a label. Entry of this amendment to the specification on page 13 and the addition of claim 27 is requested.

It is respectfully submitted that none of the prior art of record teaches a label having its top and bottom and side edges sealed, as recited in new claim 27. As noted above, not even the upper and lower edges of Barre are sealed. In addition, there is no teaching in Barre that the side edges in Fig. 1, where reference numerals 1, 8, 7, 2, 9 and 4 are, and where reference numerals 6, 3 and 5 are, are sealed. Moreover, there is no basis to argue that Barre inherently seals its edges, whether they are the top and the bottom edges, or the side edges, or all of its edges. In addition, there is no teaching that the batt in Frankosky has its side edges sealed, and there is no basis to argue that the batt in Frankosky would inherently have its side edges sealed, for the reasons discussed above. Thus, claim 27 further distinguishes over the prior art of record. Allowance of this claim, as well as claims 28 – 30 which depend thereon, is earnestly solicited.

New claims 21 – 24 have been added in order to further define the structure of Applicant's invention. These claims depend on either claim 1, or claims 1 or 31, and should be allowable for the reasons discussed above with respect to these independent claims. New claim 21 recites an insulating label stock, where the face material comprises a first layer and a second layer, wherein the second layer is disposed between the thermal insulating layer and the first layer. Antecedent basis for this claim can be found in the specification generally on page 6, line 31, through page 7, line 11, taken in conjunction with Fig. 1. New claim 22 recites another face material disposed on the side of the thermal insulating layer facing away from the second layer. Antecedent basis for this claim can be found in specification on page 6, lines 12 – 14, on page 7, lines 9 and 10, and also in Fig. 1. New claim 23 recites an adhesive primer layer applied to the surface of the face material facing away from the thermal insulating layer. Antecedent basis for this claim can be found in the specification on page 10, lines 5 - 12. New claim 24 further recites a release liner provided on the surface of the adhesive primer layer facing away from the face material. Antecedent basis for this claim can be found in the specification on page 10, lines 12 - 16.

In addition, new claims 25 and 26 should be allowable since they are dependent on claim 11 and further define Applicant's dual layer structure. New claim 25 recites that the insulating label stock of the present invention further includes a second sheet of coextruded film, wherein the second sheet of coextruded film comprises a first layer and a second layer and is disposed on the side of the thermal insulating layer opposite the first sheet of coextruded film. Antecedent basis for this

claim can be found generally in the specification from page 6, line 31 through page 7, line 11, taken in combination with Fig. 1. New claim 26 recites that the coextruded film of the first layer and of the second layer is a biaxially oriented polyester film.

New claims 28 and 29 have been added to further define Applicant's structure. New claim 28 recites that the face material comprises a first layer and a second layer, and is dependent on claim 27, which recites a label having a thermal insulating layer having a thermal resistance in the range of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2.K/W). Claim 29 is dependent on claim 27 and recites the face material further comprises a second sheet of coextruded film, wherein the second sheet of coextruded film comprises a first layer and a second layer and is disposed on the side of the thermal insulating layer opposite the first sheet of coextruded film. Claim 30 recites that the face material comprises a biaxially oriented polyester film. Antecedent basis for the recitation in claim 28 that the face material comprises a first layer and a second layer can be found in claim 11 as originally filed, as well as in the specification on page 6, line 31 through page 7, line 17, as well as Figs. 1 and 2. Antecedent basis for the recitation in claim 28 that the second layer is disposed between the thermal insulating layer and the first layer can be found in the specification generally on page 6, line 31, through page 7, line 11, taken in conjunction with Figs. 1 and 2. Antecedent basis for the recitation in claim 28 that the face material comprises a first sheet of coextruded film can be found in the specification on page 6, line 31 through page 7, line 2. Antecedent basis for the recitation in claim 29 that the face material comprises a second sheet of coextruded film which comprises a first layer and a second layer and is disposed on the side of the thermal insulating layer opposite the first sheet of coextruded film can be found in the specification on page 7, lines 9 – 17, read in conjunction with Fig. 1. Entry of claims 28 and 29 is respectfully requested. Claims 28 and 29 should be further allowable, along with the reason that they should be allowable as discussed with respect to claim 27 above, and also for the reasons discussed above with respect to claim 11 below, namely, that Barre does not disclose a thermal insulating layer having a thermal resistance in the range of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2.K/W).

New claims 20, 26 and 30 depend on either claims 1 or 31, 11 or 27, and should be allowable for the reasons discussed above with respect to these independent claims. These claims have been added in order to further define the structure and materials of Applicant's invention. Claims 20, 26 and 30 further recite
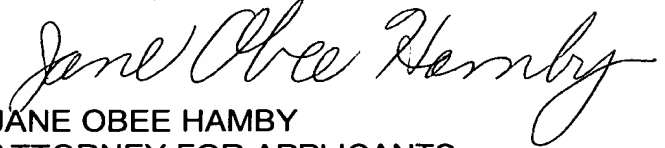
that the face material is a biaxially oriented polyester film. Antecedent basis for these new claims can be found in the specification on page 8, lines 8 and 9. Entry of claims 20, 26 and 30 and allowance of these claims is also requested.

New claim 32 recites that the thermal insulating layer has a thermal resistance in the range of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2.K/W). This feature is a patentable distinction over the prior art as discussed above. New claim 33 recites that the face material is laminated to one side of the thermal insulating layer, and further comprises another face material laminated to the other side of the thermal insulating layer. Antecedent basis for this claim can be found on page 7, lines 9 and 10, as well as Fig. 1. Entry and allowance of these claims is further requested.

New claim 34 also distinguishes over the prior art of record by virtue of the fact that it recites that the label stock has upper and lower edges, and that the upper and lower edges of the label stock are sealed. Claim 34 also claims a thermal insulating layer having a thermal resistance in the range of 0.05 to 0.5 CLO (0.0077 to 0.077 m^2.K/W). As discussed above, all of these recitations represent patentable features, in and of themselves, and proper antecedent basis for these limitations can be found in the specification as discussed above. Thus, claim 34 should be entered and allowed for these further reasons.

A Petition for an Extension of Time for two months is filed concurrently herewith. Should any further extension of time be necessary, the Examiner is authorized to take such further extension and charge the fee for such further extension to Deposit Account No. 04-1928 (E.I. du Pont de Nemours and Company).

Respectfully submitted,

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Enclosures: Attachments A, B, C and D

ATTACHMENT A

Thermal resistance values for high-density, medium density and low density polypropylene, polyethylene and polyester fibers, and polyethylene terephthalate the materials disclosed for non-woven film 8 in Barre, were calculated as follows. Attached are pages 737 and 738,from the Encyclopedia of Polymer Science and Engineering, Volume 16. These pages include Table 6, Thermal Properties of Polymers and Polymer Composites at 20°C. In this Table, thermal conductivity in W/(m•K) is given in the first column for the above-listed materials.

Thermal resistance values were calculated for both a 20 μm thickness and a 500 μm thickness, which is the widest thickness range disclosed in Barre, for the above materials.*

1. For polypropylene with a Thermal Conductivity value, C, of 0.12 W/m•K

A. For 20 μm:

To calculate the inverse of thermal resistance, C^I, which is given in terms of W/ m^2•K, one divides thermal conductivity by thickness, as can be deduced from the attached Appendix. For a 20 μm sample,

$$C^I = \frac{0.12\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 6000\ \frac{W}{m^2 \bullet K}$$

R = 1/C^I, as can be seen from the units of the attached Appendix.

Therefore, R = 0.00016 m^2•K/W at 20 μm

B. For 500 μm:

Similarly,

$$C^I = \frac{0.12\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 240\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 0.00417 m^2•K/W at 200 μm

*Note: If the thickness of the substrate falls within the range of 20 μm to 500 μm, then the thermal resistance would also fall within the range of 0.00016 and 0.00417, and would still be less than Applicant's claimed range of 0.0077 to 0.077 m^2•K/W.

2. For 40% talc filled polypropylene with a Thermal Conductivity value, C, of 0.32 W/m•K

A.   For 20 µm:

$$C^I = \frac{0.32 \text{ W}}{\text{m} \cdot \text{K}} \times \frac{1,000,000 \text{ µm}}{\text{m}} \times \frac{1}{20 \text{ µm}} = 16000 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

Therefore, R = 1/C^I = 0.00006 $\text{m}^2 \cdot \text{K/W}$ at 20 µm

B.   For 500 µm:

$$C^I = \frac{0.32 \text{ W}}{\text{m} \cdot \text{K}} \times \frac{1,000,000 \text{ µm}}{\text{m}} \times \frac{1}{500 \text{ µm}} = 640 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

Therefore, R = 1/C^I = 0.00156 $\text{m}^2 \cdot \text{K/W}$ at 20 µm

3.   For 40% $CaCO_3$ filled polypropylene with a Thermal Conductivity value, C, of 0.29 W/ m•K

A.   For 20 µm:

$$C^I = \frac{0.29 \text{ W}}{\text{m} \cdot \text{K}} \times \frac{1,000,000 \text{ µm}}{\text{m}} \times \frac{1}{20 \text{ µm}} = 145000 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

Therefore, R =1/C^I = 0.00007 $\text{m}^2 \cdot \text{K/W}$ at 20 µm

B.   For 500 µm:

$$C^I = \frac{0.29 \text{ W}}{\text{m} \cdot \text{K}} \times \frac{1,000,000 \text{ µm}}{\text{m}} \times \frac{1}{500 \text{ µm}} = 580 \frac{\text{W}}{\text{m}^2 \cdot \text{K}}$$

Therefore, R = 0.00172 $\text{m}^2 \cdot \text{K/W}$ at 500 µm

4.   For 40% glass reinforced polypropylene with a Thermal Conductivity value, C, of 0.37 W/ m•K

A.   For 20 μm:

$$C^{l} = \frac{0.37 \frac{W}{m \bullet K}}{m^{2} \bullet K} \quad \times \quad \frac{1,000,000 \text{ μm}}{m} \quad \times \quad \frac{1}{20 \text{ μm}} \quad = \quad 185000$$

Therefore, R =1/C^{l} = 0.00005 $m^{2} \bullet K/W$ at 20 μm

B.   For 500 μm:

$$C^{l} = \frac{0.37 \text{ W}}{m \bullet K} \quad \times \quad \frac{1,000,000 \text{ μm}}{m} \quad \times \quad \frac{1}{500 \text{ μm}} \quad = \quad 740 \frac{W}{m^{2} \bullet K}$$

Therefore, R = 0.00135 $m^{2} \bullet K/W$ at 500 μm

5.   For low density polyethylene with a Thermal Conductivity value, C, of 0.33 W/ m•K

A.   For 20 μm:

$$C^{l} = \frac{0.33 \frac{W}{m \bullet K}}{m^{2} \bullet K} \quad \times \quad \frac{1,000,000 \text{ μm}}{m} \quad \times \quad \frac{1}{20 \text{ μm}} \quad = \quad 16500$$

Therefore, R =1/C^{l} = 0.00006 $m^{2} \bullet K/W$ at 20 μm

B.   For 500 μm:

$$C^{l} = \frac{0.33 \text{ W}}{m \bullet K} \quad \times \quad \frac{1,000,000 \text{ μm}}{m} \quad \times \quad \frac{1}{500 \text{ μm}} \quad = \quad 660 \frac{W}{m^{2} \bullet K}$$

Therefore, R = 0.00151 $m^{2} \bullet K/W$ at 500 μm

6.   For medium density polyethylene with a Thermal Conductivity value, C, of 0.42 W/ m•K

A.   For 20 μm:

$$C^{l} = \frac{0.42 \frac{W}{m \bullet K}}{m^{2} \bullet K} \quad \times \quad \frac{1,000,000 \text{ μm}}{m} \quad \times \quad \frac{1}{20 \text{ μm}} \quad = \quad 21000$$

Therefore, R = 1/C^{I} = 0.00005 m^2•K/W at 20 µm

B.   For 500 µm:

$$C^{I} = \frac{0.42\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 840\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 0.00119 m^2•K/W at 500 µm

7.   For high density polyethylene with a Thermal Conductivity value, C, of 0.52 W/ m•K

A.   For 20 µm:

$$C^{I} = \frac{\dfrac{0.52\ W}{\dfrac{W}{m \bullet K}}}{m^2 \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 26000$$

Therefore, R = 1/C^{I} = 0.00004 m^2•K/W at 20 µm

B.   For 500 µm:

$$C^{I} = \frac{0.52\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 1040\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 0.00096 m^2•K/W at 500 µm

8.   For cast, rigid polyester with a Thermal Conductivity value, C, of 0.17 W/ m•K

A.   For 20 µm:

$$C^{I} = \frac{\dfrac{0.17\ W}{m \bullet K}}{m^2 \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 8500\ W$$

Therefore, R = 1/C^{I} = 0.00012 m^2•K/W at 20 µm

B.   For 500 µm:

$$C^{I} = \frac{0.17\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 340\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 0.00294 m^2•K/W at 500 µm

9.   For chlorinated polyester with a Thermal Conductivity value, C, of 0.33 W/ m•K

A.   For 20 µm:

$$C^{I} = \frac{0.33\ W}{\frac{W}{m \bullet K}\ \ m^{2} \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 16500$$

Therefore, R =1/C^{I} = 0.00006 m^{2}•K/W at 20 µm

B.   For 500 µm:

$$C^{I} = \frac{0.33\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 660\ \frac{W}{m^{2} \bullet K}$$

Therefore, R = 1/C^{I} =0.00151 m^{2}•K/W at 500 µm

10.   For polyethylene terephthalate with a Thermal Conductivity value, C, of 0.15 W/ m•K

A.   For 20 µm:

$$C^{I} = \frac{0.15\ W}{\frac{m \bullet K}{m^{2} \bullet K}} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 7500\ W$$

Therefore, R =1/C^{I} = 0.00013 m^{2}•K/W at 20 µm

B.   For 500 µm:

$$C^{I} = \frac{0.15\ W}{m \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{500\ \mu m} \quad = \quad 300\ \frac{W}{m^{2} \bullet K}$$

Therefore, R = 1/C^{I} = 0.00333 m^{2}•K/W at 500 µm

11.   For 30% glass reinforced polyethylene terephthalate with a Thermal Conductivity value, C, of 0.29 W/ m•K

A.   For 20 µm:

$$C^{I} = \frac{0.29\ W}{\frac{W}{m \bullet K}\ \ m^{2} \bullet K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 14500$$

Therefore, R =1/C' = 0.00007 m²•K/W at 20 μm

B.   For 500 μm:

C' = $\dfrac{0.29\text{ W}}{\text{m}\bullet\text{K}}$ x $\dfrac{1,000,000\text{ μm}}{\text{m}}$ x $\dfrac{1}{500\text{ μm}}$ = $580\ \dfrac{\text{W}}{\text{m}^2\bullet\text{K}}$

Therefore, R = 1/C' = 0.00172 m²•K/W at 500 μm

        Thermal resistance values for high-density polypropylene, polypropylene, polyvinyl choride, paper and polyethylene terephthalate, the materials disclosed for substrate 2 in Barre, were calculated as follows. Also attached is page 250 from the <u>Handbook of Physical and Mechanical Testing of Paper and Paperboard</u>. On page 250, Table 2 are given the thermal conductivity values for various types of paper.

        Thermal resistance values were calculated for both a 20 μm thickness and a 200 μm thickness, which is the widest thickness range disclosed in Barre, for the above materials.

1.   Polyethylene terephthalate with a Thermal Conductivity value, C, of 0.15 W/m•K

A.   For 20 μm:

        To calculate the inverse of thermal resistance, C', which is given in terms of W/ m²•K, one divides thermal conductivity by thickness, as can be deduced from the attached Appendix. For a 20 μm sample,

C' = $\dfrac{0.15\text{ W}}{\text{m}\bullet\text{K}}$ x $\dfrac{1,000,000\text{ μm}}{\text{m}}$ x $\dfrac{1}{20\text{ μm}}$ = $7500\ \dfrac{\text{W}}{\text{m}^2\bullet\text{K}}$

R = 1/C', as can be seen from the units of the attached Appendix.

Therefore, R = 0.00013 m²•K/W at 20 μm

B.   For 200 μm:

        Similarly,

C' = $\dfrac{0.15\text{ W}}{\text{m}\bullet\text{K}}$ x $\dfrac{1,000,000\text{ μm}}{\text{m}}$ x $\dfrac{1}{200\text{ μm}}$ = $750\ \dfrac{\text{W}}{\text{m}^2\bullet\text{K}}$

Therefore, R = 1/C' = 0.00133 m²•K/W at 200 μm

2.   30% glass reinforced polyethylene terephthalate with a Thermal Conductivity value, C, of 0.29 W/m•K

A.   For 20 µm

$$C^{I} = \frac{0.29\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{20\ µm} = 145\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 1/C^{I} = 0.00007 m²•K/W at 200 µm

B. For 200 µm

$$C^{I} = \frac{0.29\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{200\ µm} = 750\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 1/C^{I} = 0.00069 m²•K/W at 200 µm

3.   For high density polyethylene with a Thermal Conductivity value, C, of 0.52 W/m•K

A.   For 20 µm

$$C^{I} = \frac{0.52\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{20\ µm} = 26000\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 1/C^{I} = 0.00004 m²•K/W at 20 µm

B. For 200 µm

$$C^{I} = \frac{0.52\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{200\ µm} = 2600\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 1/ C^{I} = 0.00038 m²•K/W at 200 µm

4.   For 40% talc filled polypropylene with a Thermal Conductivity value, C, of 0.32 W/ m•K

A.   For 20 µm

$$C^{I} = \frac{0.32\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{20\ µm} = 16000\ \frac{W}{m^2 \bullet K}$$

Therefore, R = 1/C^{I} = 0.00006 m²•K/W at 20 µm

B. For 200 µm

$$C^{I} = \frac{0.32\ W}{m \bullet K} \times \frac{1,000,000\ µm}{m} \times \frac{1}{200\ µm} = 1600\ \frac{W}{m^2 \bullet K}$$

Therefore, $R = 1/C^{I} = 0.00062$ m^2•K/W at 200 µm

5.   For 40% CaCO$_3$ filled polypropylene with a Thermal Conductivity value, C, of 0.29 W/ m•K

A. For 20 µm

$$C^{I} = \frac{0.29 \text{ W}}{\text{m•K}} \quad x \quad \frac{1,000,000 \text{ µm}}{\text{m}} \quad x \quad \frac{1}{20 \text{ µm}} \quad = \quad 145 \frac{\text{W}}{\text{m}^2\text{•K}}$$

Therefore, $R = 1/C^{I} = 0.00007$ m^2•K/W at 200 µm

B.   For 200 µm

$$C^{I} = \frac{0.29 \text{ W}}{\text{m•K}} \quad x \quad \frac{1,000,000 \text{ µm}}{\text{m}} \quad x \quad \frac{1}{200 \text{ µm}} \quad = \quad 750 \frac{\text{W}}{\text{m}^2\text{•K}}$$

Therefore, $R = 1/C^{I} = 0.00069$ m^2•K/W at 200 µm

6.   For 40% glass reinforced polypropylene with a Thermal Conductivity value, C, of 0.37 W/ m•K

A. For 20 µm

$$C^{I} = \frac{0.37 \text{ W}}{\text{m•K}} \quad x \quad \frac{1,000,000 \text{ µm}}{\text{m}} \quad x \quad \frac{1}{20 \text{ µm}} \quad = \quad 18500 \frac{\text{W}}{\text{m}^2\text{•K}}$$

Therefore, $R = 1/C^{I} = 0.00005$ m^2•K/W at 200 µm

B.   For 200 µm

$$C^{I} = \frac{0.37 \text{ W}}{\text{m•K}} \quad x \quad \frac{1,000,000 \text{ µm}}{\text{m}} \quad x \quad \frac{1}{200 \text{ µm}} \quad = \quad 1850 \frac{\text{W}}{\text{m}^2\text{•K}}$$

Therefore, $R = 1/C^{I} = 0.00054$ m^2•K/W at 200 µm

7.   For rigid polyvinylchloride with a Thermal Conductivity value, C, of 0.21 W/ m•K

A.   For 20 μm

$$C' = \frac{0.21\ W}{m•K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 10500\ \frac{W}{m^2•K}$$

Therefore, R = 1/C' = 0.000095 m²•K/W at 200 μm

B.   For 200 μm

$$C' = \frac{0.21\ W}{m•K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{200\ \mu m} \quad = \quad 1050\ \frac{W}{m^2•K}$$

Therefore, R = 1/C' = 0.00095 m²•K/W at 200 μm

8.   For flexible polyvinylchloride with a Thermal Conductivity value, C, of 0.17 W/m•K

A.   For 20 μm

$$C' = \frac{0.17\ W}{m•K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 8500\ \frac{W}{m^2•K}$$

Therefore, R = 1/C' = 0.00012 m²•K/W at 200 μm

B.   For 200 μm

$$C' = \frac{0.17\ W}{m•K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{200\ \mu m} \quad = \quad 850\ \frac{W}{m^2•K}$$

Therefore, R = 1/C' = 0.00117 m²•K/W at 200 μm

9.   For chlorinated polyvinylchloride with a Thermal Conductivity value, C, of 0.14 W/ m•K

A.   For 20 μm

$$C' = \frac{0.14\ W}{m•K} \quad x \quad \frac{1,000,000\ \mu m}{m} \quad x \quad \frac{1}{20\ \mu m} \quad = \quad 7000\ \frac{W}{m^2•K}$$

Therefore, R = 1/C' = 0.00014 m²•K/W at 200 μm

B.   For 200 µm

$C^{I} =$ $\dfrac{0.14\ W}{m \bullet K}$ x $\dfrac{1,000,000\ \mu m}{m}$ x $\dfrac{1}{200\ \mu m}$ = $700\ \dfrac{W}{m^{2} \bullet K}$

Therefore, R = $1/C^{I}$ = 0.0014 $m^{2} \bullet K/W$ at 200 µm

10.   For paper with a Thermal Conductivity value, C, of 6 x 10 -2 W/ m•K

A.   For 20 µm

$C^{I} =$ $\dfrac{0.06\ W}{m \bullet K}$ x $\dfrac{1,000,000\ \mu m}{m}$ x $\dfrac{1}{20\ \mu m}$ = $3000\ \dfrac{W}{m^{2} \bullet K}$

Therefore, R = $1/C^{I}$ = 0.0003 $m^{2} \bullet K/W$ at 200 µm

B.   For 200 µm

$C^{I} =$ $\dfrac{0.06\ W}{m \bullet K}$ x $\dfrac{1,000,000\ \mu m}{m}$ x $\dfrac{1}{200\ \mu m}$ = $300\ \dfrac{W}{m^{2} \bullet K}$

Therefore, R = $1/C^{I}$ = 0.0033 $m^{2} \bullet K/W$ at 200 µm

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Styrene Polymers
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Tabl 6. Th rmal Pr p rties of Polymers and P lymer Comp   ites at 20°C[a]

Material	Thermal conductivity, W/(m·K)	Specific heat capacity,[b] J/(kg·K)	Linear thermal expansivity, 10^{-6} m/(m·K)
ABS, poly(acrylonitrile-co-butadiene-co-styrene)			
injection molding grade	0.33	1465	72
20% glass reinforced	0.20		20
acetal resin	0.23	1465	78
polyacrylonitrile	0.26	1285	66
polybutadiene, extrusion grade	0.22		150
polybutylene		1885	150
poly(butylene terephthalate)	0.29		77
30% glass reinforced	0.29		25
polycarbonate	0.20	1255	57
10% glass reinforced	0.22		35
30% glass reinforced	0.32		23
cellulose acetate	0.20	1255	140
cellulose acetate butyrate	0.33	2090	125
polychloroprene	0.19	2175	
polychlorotrifluoroethylene	0.29	875	54
poly(diallyl phthalate) resin	0.21	2200	75
epoxy resin			
casting grade	0.19		55
silica filled	0.84		30
aluminum filled	1.1		5
molding grade	0.16	1045	65
30% mica filled	0.24		47
50% mica filled	0.39		41
polyester			
cast, rigid	0.17	1045	78
chlorinated	0.33		30
polyethylene			
low density	0.33	2300	200
medium density	0.42	2300	150
high density	0.52	2075	120
poly(ethylene terephthalate)	0.15	1425	65
30% glass reinforced	0.29		25
polyimide, thermoplastic	0.11		52
polyisoprene	0.13	1885	
poly(methyl methacrylate)	0.21	1400	45
⊥ to stretch			38
∥ to stretch			65
nylon-6	0.24	1675	83
nylon-6,6	0.24	1675	80
nylon-6,10	0.22	1675	90
phenol–formaldehyde resin			
casting grade	0.15	1465	68
molding grade	0.25	1465	42
phenol–furfural resin, molding grade	0.25	1460	40
poly(phenylene sulfide)	0.29		49
polypropylene	0.12	2350	80
40% talc filled	0.32		61
40% CaCO₃ filled	0.29		40
40% glass reinforced	0.37		30

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Table 6. (*Continued*)

Material	Thermal conductivity, W/(m·K)	Specific heat capacity,[b] J/(kg·K)	Linear thermal expansivity, 10^{-6} jm/(m·K)
silicone resin			
casting grade	0.31		30
polystyrene	0.14	1190	65
heat resistant	0.13		77
high impact	0.80	1465	200
foam, $d = 16$ kg/m³	0.040		
$d = 32$ kg/m³	0.036		
$d = 64$ kg/m³	0.033		
$d = 96$ kg/m³	0.036		
$d = 160$ kg/m³	0.039		
polysulfone		1295	54
polytetrafluoroethylene	0.25	1045	95
polyurethane			
casting resin	0.21	1800	150
elastomer	0.31	1775	150
foam			
air blown, $d = 64$ kg/m³	0.036		
CO₂ blown, $d = 64$ kg/m³	0.016		
20% closed cells	0.033		
90% closed cells	0.016		
500 μm cell size	0.024		
100 μm cell size	0.016		
poly(vinyl chloride)			
rigid	0.21	1000	125
flexible	0.17	1675	160
chlorinated	0.14		70
poly(vinylidene chloride)	0.13	1340	190
poly(vinylidene fluoride)	0.13	1380	106
poly(vinyl formal)			
molding grade	0.27		37

[a] Ref. 1.

[b] To convert J to cal, divide by 4.184.

and increased segmental mobility on longitudinal wave propagation; and, in the case of crystalline polymers, the relative importance of crystalline and amorphous phases.

The temperature dependence of thermal diffusivity is illustrated in Figure 15. In amorphous polymers diffusivity is seen to decrease slowly in the glassy region; break slightly at the glass-transition temperature and remain essentially constant in the rubbery region; and decrease slowly in the melt-flow region. In crystalline polymers thermal diffusivity has similar characteristics but displays a relatively deep minimum at the melting point. A detailed theory of these effects has not yet appeared.

In examining Table 7 it is important to note that virtually no studies have been reported where thermal properties are measured continuously from the glassy, through the rubbery, and into the melt-flow regions, thus affording an opportunity to investigate the effects of transitional phenomena on thermal conductivity or diffusivity. Furthermore, no reports have appeared involving the

Handbook of
Physical and Mechanical Testing
of Paper and Paperboard

VOLUME 2

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Table 2 Thermal Conductivity of Paper and Paperboard

Material	Data[a] [W/(m·K)] (all entries × 10^{-2})	Condition	References
Paper	6	Room temperature	[39]
Cardboard	21	Room temperature	[39]
Rice paper	4.6	40°C	[26]
Blotting paper	6.3	20°C	[26]
Corrugated cardboard	6.3	20°C	[26]
Cement paper, plain 14 layers, each 0.38 mm, 0.62 g/cm³	12.7	20°C	[26]
Fish paper, 21 layers,	17.2	20°C	[26]
Handsheet, bleached sulfite pulp	8.4–11.7	20°C, 50% RH	[17]
Electrical insulating paper,	4.6–7.9	100°C, vacuum	[35]
Sulfite pulp sheet, 1500 g/m²	6.7	moisture content 0%	[13]
Sulfite pulp sheet, 1500 g/m²	19	moisture content 110%	[13]
Fine paper, 0.074 mm, 0.858 g/cm³	1.3	30°C, 40% RH	[37]
Fine paper, 0.074 mm, 0.858 g/cm³	3.1	30°C, 60% RH	[37]
Fine paper, 0.074 mm, 0.858 g/cm³	3.7	60°C, 40% RH	[37]
Fine paper, 0.074 mm, 0.858 g/cm³	5.8	60°C, 60% RH	[37]
Copy paper, 0.060 mm, 0.840 g/cm³	14.6	30°C, 40% RH	[37]
Copy paper, 0.060 mm, 0.840 g/cm³	15.1	30°C, 60% RH	[37]
Copy paper, 0.060 mm, 0.840 g/cm³	16.3	60°C, 40% RH	[37]
Copy paper, 0.060 mm, 0.840 g/cm³	17.0	60°C, 60% RH	[37]

[a]All data re converted from ca./(cm · s · °C) or kcal/(m · h · °C) to W/(m · K).

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OPERATION MANUAL

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Holometrix, Inc.
25 Wiggins Avenue, Bedford, MA 01730-2323 USA
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Appendix 1 Conversion Between Metric and British Units

The controller can present parameters and data in terms of either SI (Metric) or British units. To convert from one format to the other format, the following information is provided:

	SI (Metric) Units	British (Br) Units	Conversion
Temperature	°C	°F	$°F = 32 + (9/5)*°C$ $°C = (°F-32)*(5/9)$
Thermal Conductivity	W/(m*°K)	(BTU*in)/ ($ft^2*°F*h$)	Br = 6.933*SI
Thermal Resistance	($m^2*°K$)/W	$°F*h*ft^2$/BTU	Br = 5.678*SI
Temperature Gradient	°K/m	°F/in	Br = 0.04572*SI
Length	cm	in	Br = SI/2.54
Density	Kg/m^3	lb/ft^3	Br = 0.0128443*SI
Δ T	°C	°F	Br = 1.8*SI

To convert from SI units to British (Br) units, multiply the numeric SI value by the indicated factor (e.g. to convert an SI thermal conductivity value to a British value, multiply the SI value by 6.933).

To convert from British (Br) units to SI units, divide the numeric British value by the indicated factor (e.g. to convert an British thermal conductivity value to a SI value, divide the British value by 6.933).

If the system is operating in a given format (e.g. SI), make certain that all data entries are entered in that format.

When the format is changed from SI to British (or vice versa) via the Units Set command, all numeric values are automatically changed using the above factors.